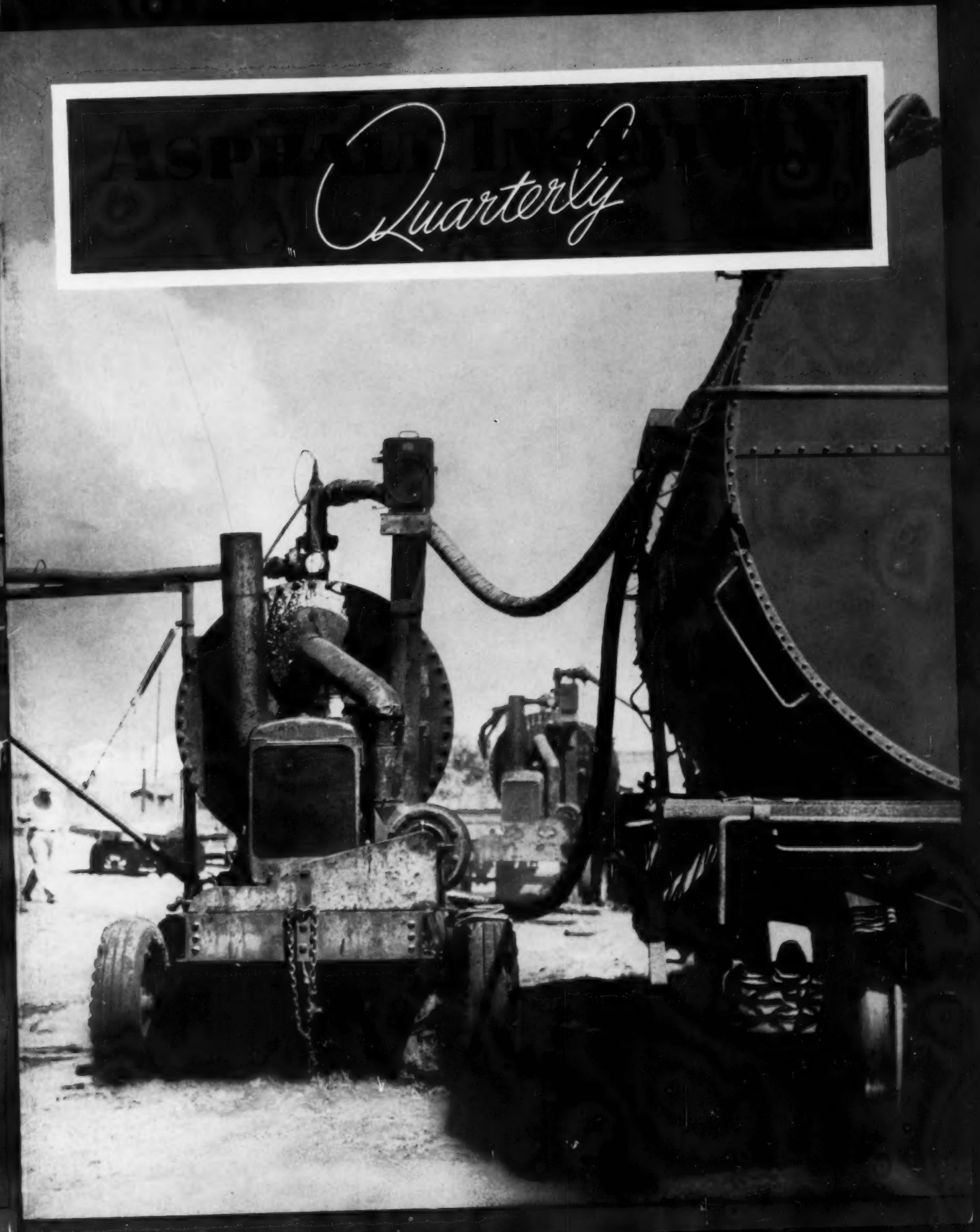
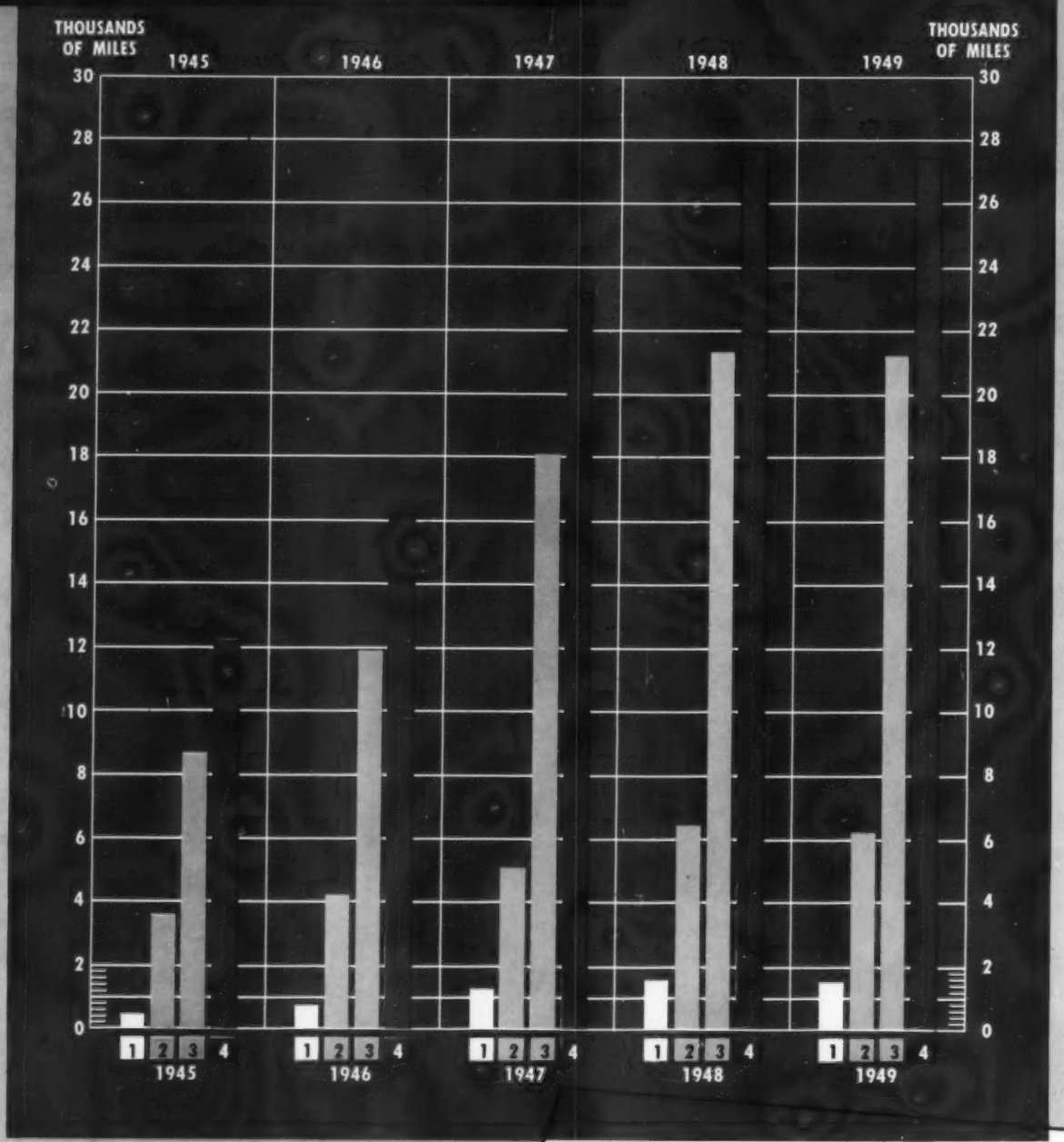
Asphalt Institute Quarterly



STATE ROAD MILEAGE BUILT

(Bituminous Types and Portland Cement Concrete)

In [illegible] of Last Five Years Reported



KEY

1 PORTLAND CEMENT CONCRETE
2 HIGH TYPE BITUMINOUS
3 LOW COST BITUMINOUS
4 COMBINED BITUMINOUS (COLUMNS 2 + 3)

CHARTED BY THE ASPHALT INSTITUTE, APRIL 1951 SOURCE: U. S. BUREAU OF PUBLIC ROADS FIGURES

Asphalt Institute Quarterly

The Asphalt Institute Quarterly is published by the Asphalt Institute, a national, non-profit organization sponsored by members of the industry for the purpose of promoting interest in the use of asphaltic products.

The names of the Member Companies of the Institute, who have made possible the publication of this magazine, are listed herein on page 15.

EDITORS

Bernard E. Gray, *President of The Asphalt Institute*
Ernest M. Bristol, *Director of Public Relations*

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COVER

Featured on the double covers is a picture of an asphalt transfer operation, taken at Terrell, Texas, by Hugh Wallace, Division Engineer, The Asphalt Institute. In this operation the undersealing asphalt is pumped from the tank car through a circulating type car heater, where temperatures are boosted. The material is then delivered to the distributor *(back cover)* for transport to the project.

This graphic chart illustrates the comparative mileage situation, as it has recently been developing, in regard to the choice of pavement types for State Highways. In the last five years reported, this has been 95% bituminous and 5% portland cement concrete—*more predominantly asphalt than ever before.*

EDITORIAL

The Greeks had a word for it, *"asphaltos,"* by derivation a material for *binding* or *cementing together.* The asphalt of early times was found in shallow deposits where petroleum once had exuded to the surface and subsequently, through the natural processes of wind and sun, had been refined and the lighter portions evaporated. These natural asphalts were prized highly by the ancient peoples and the cementing qualities were first used to bind together precious and semi-precious stones in the manufacture of jewelry and ornaments. As more and larger deposits were discovered, the use extended to binding together common stones and bricks; and portions of streets and various kinds of structures, so bonded, are still intact after the passage of thousands of years. Thus asphalt has not only the ability to cement together, but also the priceless quality of durability, the property of lasting under changing conditions of temperature and moisture for a long, long time.

Today, asphalt is refined from petroleum in large stills under carefully controlled conditions of pressure and temperature, so that the exact qualities desired may be secured quickly and in sufficient amount to meet the growing modern demand. In 1950 there was used in the United States almost twice the amount of asphalt cement used in 1940, only ten years earlier. Including all grades of asphaltic materials this amounted to over eleven and a half million tons which, if delivered by railroad, would have required nearly 300,000 tank cars. Asphalt cement is used largely in paving, approximately 70% being so employed each year in the building and maintaining of roads, streets, airfields, parking and recreational areas of all kinds. The remainder goes into roofing, waterproofing and industrial uses of a thousand varieties, where these same qualities of *cementing* and *durability* are so important.

In cementing, however, asphalt possesses a special additional property. Out of long experience and observation of behaviour has come the realization that it can *yield slightly without losing binding qualities.* This property of controlled plastic flow is most valuable and permits use of the material in various kinds of work where rigid construction would lead to failure. Thus there are being developed new groups of uses, either supplemental to present established procedures or in quite new forms of application.

Described in this issue of the Quarterly are several such uses, which are examples of the manner in which asphaltic products may be adapted to the extreme variations of temperature and moisture. *Undersealing* is a development of the last decade, the principal application at present being stabilization and waterproofing of old concrete roads. It is evident, however, that the same general process is applicable to structures of all kinds where subsurface cavities require filling with a material which can give slightly without breaking and which will remain unchanged over the years regardless of heat or cold, dryness or water saturation. There is also the wide development for rip-rap and jetties in water control, and the use with hydraulic structures to prevent leakage.

Examples of these developments are reported herein, not only for the factual data contained, but also because, as so often in engineering history, these experiences may suggest the solution to problems in other allied fields.

ASPHALT UNDERSEAL FOR CONCRETE PAVEMENTS

By WALTER F. WINTERS

The title of a recent article in the Saturday Evening Post, "Hypodermics For Tired Highways", aptly describes this important treatment of concrete pavements. "Tired highways" might indicate to some that only the older concrete requires an underseal, but this is not necessarily true, since in many comparatively new highways continual slab movement under traffic is pointing to the ultimate destruction of that pavement. Vertical concrete slab movements result in several subgrade actions, either increased consolidation of the subgrade or, if moisture is present, in the *pumping* out of the supporting subgrade material. The net result of either action is the same, the creation of holes and voids beneath the concrete slab and the loss of adequate support. When proper support is lacking repetitive loading will eventually crack and destroy the slab.

An undersealing operation on U.S. 175, southeast of Kaufman, Texas. *Photo Wallace.*

METHODS USED

Restoring proper support to flexing concrete pavements has been a long felt need of the highway engineer, and many methods have been used, few of which were satisfactory until the technique of asphalt underseal was developed. Probably the first effective use of asphalt underseal occurred in Ohio in 1942. In these initial projects, holes were bored through the concrete and various types of asphaltic materials introduced under the slab by pumping with an ordinary distributor. After some experimentation it was decided by the Ohio Highway Department that a 30-45 penetration oxidized asphalt with a softening point of 165°F. was the proper material to use. The undersealing in Ohio was followed in 1944 and 1945 by some rather extensive projects in the States of Texas and California. These latter operations were quite similar to those conducted in Ohio, except that in the warmer climates a heavier type of asphalt was used to prevent extrusion of the underseal during hot weather. California used 10-25 penetration oxidized asphalt with a softening point of about 200°- 225°F., and Texas a 25-35 penetration oxidized asphalt with a softening point of 185°F.

Undersealing of concrete pavements with asphalt is now extensively used throughout the country and there are but few states which do not employ this treatment for the stabilizing of concrete slabs. Millions of gallons of asphalt are so used each year. In most states it is standard practice to underseal prior to resurfacing with asphaltic materials.

It has been reported by some states that asphalt undersealing has stopped as much as 95% of the slab movement of the concrete. A recent study at the Air Force Base, by the Air Installation Division at Columbus, Mississippi, showed the following results in the accelerated traffic tests. A test track was prepared in Columbus using portland cement concrete paving, half of which was treated with an asphalt subseal and the other half left untreated. When tested to failure this track showed that in the *untreated* area 87½% of the slabs were total failures. Of the remaining slabs, 12% were in a state of major distress and all slabs were cracked. In the *asphalt subsealed* section but 12½% of the track showed failure, with 24½% of the slabs unfractured, and 87½% still fit for travel.

As is true with almost every type of engineering project, the larger asphalt underseal jobs are much more economical to construct than the smaller ones. For example, in Texas in the first four mile project the drilling and preparation of holes in the concrete cost $0.33 each, and the furnishing and applying of asphalt $0.147 per gallon. These costs were reduced on later 40 and 50 mile jobs to $0.05 for drilling and preparation of holes and approximately $0.11 per gallon for asphalt furnished and applied.

CONSTRUCTION PROCEDURES ESTABLISHED

Methods and techniques of underseal vary considerably throughout the country, but in general, the following methods are used. Somewhat regular patterns of 1½ inch holes are drilled through the concrete pavement, spaced at intervals from 10 to 20 feet. These holes are alternated across the center line of the pavement and are placed about 3 feet from center line. Holes are seldom placed nearer than 18 to 24 inches from any joint or crack. In addition to the set of pattern holes a condition survey of the pavement is made by sounding the pavement with an iron bar, and holes are drilled where a hollowness is indicated by the sounding.

In some states where the concrete is easy to drill and the cost of the holes is low, holes are spaced on an average of one per ten yards of pavement. Where this spacing is used, there are times when but 50 to 65% of the drill holes are used for pumping asphalt under the pavement. The balance serve as inspection holes to gauge the travel of the asphalt and then are stopped with wooden plugs when the asphalt appears in that area.

Holes are drilled through the concrete by many different methods. In some areas, where a regular pattern of holes is used, drilling jigs have been devised with an air-drill at each hole point. This method is somewhat cumbersome, and the system finding most favor at this time is the air-lift type drill mounted on a pneumatic wheeled tractor carrying the compressor. Such drills are sometimes equipped with a swinging boom carrying an air-drill which will allow one operator to drill two holes or more at one time. In some areas where the concrete aggregates are extremely hard, tungsten carbide bits have been used with considerable success since bit replacement is thereby reduced materially.

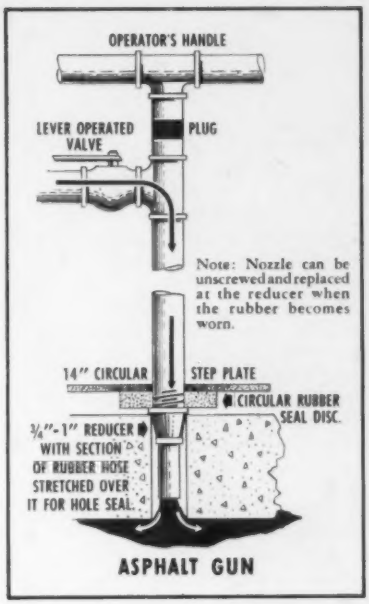
The asphalt for undersealing is usually shipped by tank car or transport truck to a point near the project. Normally, temperatures of the asphalt on arrival are sufficiently high to allow pumping from the tank car through a retort or booster heater which raises the temperature to about 425°F. Occasionally, a tank car which has been delayed in transit will arrive on a job in a solid state. When this condition exists, the car can be broken down to the pumping temperature by several methods. Steam may be applied to the tank car coils and the heavy material softened in this manner. This is rather a slow method and at times may take three or four days. A better system sometimes used is to place both the inlet and outlet hose of the booster heater through the dome of the tank car, and so start a pool of hot asphalt in the top of the mass. By circulating this hot asphalt through the heater and returning to the tank car, the temperature of the cold asphalt can soon be raised a sufficient amount to allow pumping.

Asphalt is hauled to the job by a service tank truck or distributor depending on the haul involved. The process of applying the asphalt underseal is a simple one. A standard highway asphalt distributor is normally used for this purpose. Any distributor having a capacity of 500 gallons or more and equipped with a rotary positive pressure type pump and full circulating asphalt delivery line can be used satisfactorily. In most undersealing operations distributors are equipped with two sets of pumping hoses of appropriate lengths in order that two holes may be treated with asphalt at one time. Prior to application of the asphalt, the hole in which the asphalt is to be introduced is blown out with an air hose to allow free access of the bituminous material.

EQUIPMENT DEVELOPED

To introduce asphalt through the hole to the voids underneath the pavement several different devices are in use, the most common being a metal tapered nozzle approximately 12" long having a one inch bore and an outside diameter of 2" at the top and 1¼" at the bottom. This nozzle is arranged with an offset for by-pass valves and delivery lines in such a manner that it can be driven into the hole and after pumping, can be removed with a forked wrench. The California Highway Department has developed a tapered nozzle which incorporates a ball type check-valve. The upper end of this nozzle is equipped with a quick-connecting coupler which can be connected or disconnected with the operating handle at each hole. A number of these plugs are driven in holes ahead of the asphalt appliers, and the operators attach the asphalt applicator to each nozzle in succession while in the process of the pumping operation.

Another simple device used is the Asphalt Gun illustrated above. This asphalt applicator has found favor with many users because of its simplicity, and the fact that it can be constructed out of water pipe and fittings in their own shops. On this device, the lower end consists of a ¾" nipple and a ¾" to 1" reducer, with a piece of radiator hose stretched over the reducer. This section can be removed and replaced when the rubber becomes worn, during the pumping applications, thus insuring a tight connection at the hole. Normally, full circulating lines connect the nozzle to the distributor, with a


OPERATOR'S HANDLE
LEVER OPERATED VALVE
PLUG
Note: Nozzle can be unscrewed and replaced at the reducer when the rubber becomes worn.
14" CIRCULAR
STEP PLATE
CIRCULAR RUBBER SEAL DISC.
¾"-1" REDUCER WITH SECTION OF RUBBER HOSE STRETCHED OVER IT FOR HOLE SEAL.
ASPHALT GUN

by-pass valve located at the applicator in order that when the pumping is stopped at each hole, a full circulation of hot asphalt will be had between the applicator and the distributor. In some locations pumping operations are conducted with a single hose connecting the distributor and the applicator, since one hose is much less cumbersome for the operator to handle than the two hoses. However, in an installation of this nature, the operator of the nozzle must be very familiar with the operation in order to prevent the asphalt from congealing in the single hose during the time lag between hole applications.

Asphalt is pumped from the distributor underneath the slab at 30-40 pounds per square inch of pressure. The temperature of the asphalt at this time should be approximately 400°F. Usually pumping is continued under the slab until a slight upward movement has been noticed. If the hot asphalt tends to extrude from adjacent cracks or joints the nozzle is shut off for a short period of time in order to allow the extruded asphalt to cool and form a seal over the

Continued on Page 6

ASPHALT UNDERSEAL

Continued

crack before pumping is resumed. If it is desired to adjust the vertical alignment of the slab, pumping is continued until the slab has reached the proper grade. When sufficient asphalt has been pumped into any one hole the asphalt applicator is quickly removed, and a temporary soft wooden plug, tapered to fit the hole tightly and about 3′ long, is quickly driven to prevent back pressure escape of the asphalt. Prior to applying the asphalt, the area around the hole is usually wet down or covered with a thin layer of soil or sand, thus simplifying removal of the excess asphalt around the hole after pumping has been completed. After the asphalt has cooled, the temporary plug is withdrawn, the excess asphalt is removed, and a soft wooden plug driven flush to the pavement in the hole, or filled with bituminous or other materials.

CONCLUSIONS REACHED

Undersealing asphalt can be applied beneath slabs when free water is present. However, it is generally advisable to use slightly higher pumping pressures and hotter asphalts when this condition exists. It has been noted that if the concrete pavement is substantially shattered and badly out of alignment, little good can be accomplished by asphalt underseal, since it is necessary to confine travel of the hot asphalt underneath the slab in order to obtain proper coverage. Considerable extrusion will take place in shattered pavements.

Costs of asphalt undersealing will vary considerably throughout the country depending on the hardness of the concrete, the age and condition of the pavement, the amount of rainfall and subdrainage, the availability of materials, and many other factors. On the average throughout the country three hundred to seven hundred holes per mile will be required. An average of about 10 gallons of asphalt per hole will be used. Drilling, blowing, and grouting the holes will cost from $0.10 to $0.30 per hole, and asphalt furnished and applied will cost from $1.50 to $2.50 per hole. Due to this wide variance in cost, the completed asphalt undersealing job will range from $800 to $2000 per mile.

Extensive asphalt undersealing programs for portland cement concrete pavements have become a "must" in a majority of the states due to the extensive resurfacing and widening programs now necessary on concrete pavements. It is usually necessary from an engineering standpoint to underseal with asphalt *prior to resurfacing*, in order to stabilize the slabs and prevent rocking and movement underneath the resurfacing materials. All things considered, it can certainly be said that the cost of this protection is but little when compared to the benefits to be derived from the resulting smoother riding surfaces and other lasting improvements, which will give new life to "tired" concrete pavements for many years to come.

END

GENERAL OUTLINE OF SPECIFICATIONS

For Undersealing Portland Cement Concrete with Asphalt

These specifications include five sections, entitled respectively, *Description, Materials, Construction, Method of Measurement, and Basis of Payment;* followed by a comprehensive discussion of *Preventive maintenance procedure, Equipment requirements, Safety requirements, Spacing of holes, Asphalt temperature control, Precautions when pumping asphalt, Quantity of asphalt and Joints and cracks.*

Important extracts from these tentative specifications follow.

PRESSURE DISTRIBUTORS

Pressure distributors used shall be self-propelled or semi-trailer type equipped with pneumatic tires. The tanks for distributors shall have a minimum capacity of 500 gallons, be insulated and equipped with removable manhole covers, have a 2 inch overflow pipe and suitable strainers at the outlet to the pumps. A dial gauge shall be provided to indicate the contents of the tank at various levels and a pressure gauge to show the pressure at which asphaltic material is being applied. An accurate mercury actuated thermometer with a range covering the specified application temperature shall be mounted at approximately the center height of the tank well extending into the asphaltic material in such a way that it is not in contact with a heating tube.

Distributors shall be equipped with approved heating systems and with pumps of the rotary positive-pressure type, driven by a motor other than that propelling the truck, and capable of applying asphaltic material at a pressure of 20 to 60 pounds per square inch.

PREPARATION OF ASPHALT

The asphalt shall be heated to a temperature of between 325°F. and 425°F., at the direction of the Engineer. As much of the heating as possible shall be done in tank car or storage tank. When applying heat in a pressure distributor care must be exercised to operate the burners only when the level of the asphalt is above the flue line. The asphalt shall be circulated for a short time prior to pumping to free and warm up the lines of the circulating hose. When single line metal patching hose is provided, the hose and nozzle shall be connected and the nozzle placed in the open manhole on top of the distributor tank and the asphalt circulated to warm up the hose line.

PUMPING ASPHALT

After the holes have been blown out, as previously described, and the nozzle has been firmly wedged into the hole, asphalt shall be pumped at a pressure of from 20 to 45 pounds per square inch until the underside of the slab is sealed and all cavities filled, or until the slab has been raised the desired amount. To prevent any asphalt which may leak out from around the nozzle from sticking to the pavement, water or earth shall be sprinkled around the hole prior to pumping. If asphalt seeps from the joints or cracks before the undersealing is completed, water shall be sprinkled over the extruding asphalt and the pumping momentarily stopped until the extruded asphalt has congealed. If this does not stop the flow of asphalt, a pat of wet mud shall be held down by weight over the leaking spot. If this does not suffice, if the slab raises unevenly, or if asphalt extrudes from under one edge of the slab before the operation is completed, an additional hole shall be drilled and the process repeated.

PREVENTIVE MAINTENANCE

The undersealing of the portland cement concrete pavements or slabs to prevent water from seeping through the joints and cracks of the pavement or accumulating under the slabs from the subgrade should be performed at the first signs of distress. Water accumulating under a portland cement concrete pavement, either from the surface or the subgrade, will reduce the bearing capacity of the subgrade beneath the slab, thus allowing excessive deflection and the resultant cracking and breaking up of the pavement. This is particularly prevalent at the edges and corners of slabs where repeated loadings tend to produce additional compaction of the subgrade, leaving cavities in which surface water can accumulate and soften the subgrade. Effective undersealing of the joints and edges before this condition becomes exaggerated is highly desirable as a preventive maintenance measure.

Undersealing of portland cement concrete pavement is normally done in conjunction with resurfacing the concrete with hot-mix asphalt. Since all slabs and concrete surfaces should be as completely stabilized as possible, it is always advisable to resurface with asphalt soon after the undersealing has been done, as unsurfaced but undersealed slabs have in some cases been known to start pumping from water accumulation, when left over the winter unprotected.

SPACING OF HOLES

In general, for minor cavities or where there is no settlement of the slab, holes should be drilled 12 to 18 inches from the transverse crack or joint. Where settlement has occurred, the holes should be drilled 24 to 36 inches back from the crack or joint. For highway pavement slabs with minor cavities, one hole drilled near the center joints, 12 inches from the transverse joint on the far side, when facing in the direction of traffic flow, may suffice. One hole 36 inches from the transverse crack in the center of the traffic lane may satisfactorily raise as well as seal a more serious condition. If necessary to obtain complete under slab coverage, in addition to the joint holes described above, holes should be spaced longitudinally from 12 feet to 25 feet, depending on the condition of the pavement, and alternated across the centerline approximately 3 feet from said centerline.

For *airport runway slabs,* the holes should be drilled on alternate sides of the joints and spaced approximately 12 feet on centers. No difficulty has been encountered with slabs breaking while following this method of undersealing. Other patterns may be developed due to the particular circumstances surrounding a project, but care should be exercised to avoid breaking the slabs.

QUANTITY OF ASPHALT

The amount of asphalt required, using this method, will vary depending upon the condition of the pavement and the subgrade at the time of sealing.

Where only minor cavities exist and the slab movement has not resulted in serious pumping, as little as one-half gallon per square yard, or 15 to 20 gallons per joint, will underseal the pavement. From these minimum quantities, up to 40 to 50 gallons per joint, or possibly one and one-half gallons per square yard, may be required when a more serious condition exists. Exceptionally bad pumping joints or sunken slabs may require as much as 100 to 150 gallons per joint to completely raise and seal the pavement or slab.

JOINTS AND CRACKS

Undersealing programs should not be confused with regular (top of slab) joint and crack sealing operations. If joints and cracks require sealing, this operation should be performed in advance of and separately from an undersealing program.

SPECIFICATIONS FOR ASPHALT CEMENTS

FOR UNDERSEALING PORTLAND CEMENT CONCRETE PAVEMENTS

SPECIFICATION DESIGNATION	Softening Point Grades °F	
	160-180	180-200
	For Average Conditions	
GENERAL REQUIREMENTS	The asphalt used shall be prepared by the refining of petroleum. It shall be uniform in character, free from water, and shall not foam when heated to 350°F. It shall meet the following requirements when tested in accordance with the methods hereinafter enumerated.	
Flash Point (Cleveland Open Cup) °F.	425+	425+
Softening Point (Ring and Ball) °F	160-180	180-200
Penetration of Original Sample		
At 32°F., 200 g., 1 min.	15+	10+
At 77°F., 100 g., 5 sec.	25-40	15-30
At 115°F., 50 g., 5 sec.	90—	60—
Loss on Heating at 325°F., 5 hrs., %	1.0—	0.5—
Penetration after Loss on Heating, % of Original	70+	70+
Ductility at 77°F., in cms.	3+	2+
Solubility in Carbon Tetrachloride, %	99.0+	99.0+

Note: Asphalt for Undersealing Portland Cement Concrete is available in a special 140°-160°F. grade but is intended to be used only rarely and *where the average atmospheric temperatures are very low.*

METHODS OF TEST

Methods of test shall be the latest revisions of the following:

Softening Point, A.S.T.M. Method of Test D 36
Flash Point, A.S.T.M. Method of Test D 92
Penetration, A.S.T.M. Method of Test D 5
Loss of Heating at 325°F., A.S.T.M. Method of Test D 6
Ductility, A.S.T.M. Method of Test D 113
Solubility in Carbon Tetrachloride, A.S.T.M. Method of Test D 4, except that carbon tetrachloride shall be used instead of carbon disulphide as solvent, Method No. 1.

ASPHALT CURBS AND GUTTERS

Above: Constructing asphalt curb on U. S. 25, north of Mount Vernon, Kentucky. In the foreground, shoveling the hot-mix into position between the forms; raking and compaction operations are shown in the distance.

Below: A closeup view of the compaction operation on same curb construction project. *Described on page 9.*

With the advance in the use of the asphaltic types of pavement, the materials and equipment are becoming more readily available for constructing *asphalt curbs and gutters*. Possessed of important competitive advantages, these facilities are now coming into more general use, not only because of lower construction cost and earlier use by traffic but also their resistance to damage from salts used for ice control.

METHODS OF CONSTRUCTION

As mentioned, the use of asphalt curb and gutter has been handicapped in past years by the lack of available material and equipment. Usually construction has been by hand method. With the more general use of asphalt there is certain to be developed in the near future machine methods, such as the slip-form paver which has been used for the past five years for laying and compacting hot-mix surfacing in canals and reservoirs. The State of California has used a slip-form hot-mix paver in some highway ditch lining construction with considerable success.

U. S. 50, NEAR FAYETTEVILLE, OHIO

The details of the lip curb construction on U. S. 50, pictured at top of page, follow. The curb is 3″ high, 9″ wide at the base with 1½″ flat top at the outer edge. Briefly described, the construction method consisted of fastening a 3″ channel form with clamps to the 9″ steel form used in constructing the 8½″ hot-mix asphaltic concrete pavement proper. The hot-mix used to form the curb was spread by sliding by hand a 2″ oak template along both the top of the 3″ form and the pavement. The material thus "struck-off" was then compacted by vibrating with a jackhammer on a steel plate over the newly-spread material. The asphalt mixture was laid and compacted in two courses.

This asphalt gutter in Mount Airy Forest, Cincinnati, Ohio, is paved to the retaining wall.

A shallow gutter, paved with asphaltic concrete, on U. S. 150, in Fredericksburg, Indiana.

U. S. 25, NEAR MOUNT VERNON, KENTUCKY

Another very practical method was developed in 1949, for highway curb construction, on U. S. 25, in Kentucky, as pictured on page 8. It involved the construction of about 22,000 lineal feet of lip curb 3″ high by 9″ wide on a 22′ width of pavement consisting of 3″ of hot-mix on a water-bound macadam base. A 2″ by 4″ by 10′ timber was set on the edge of the pavement for the outer form. This was held in place by braces and stakes as is customary with curb work. The inner form consisted of ¼″ by 2″ by 10′ steel plate laid flat on the pavement and secured to it with two 10-penny nails through holes in the plate.

After the forms were set, a light tack coat of asphalt was applied to the surface where the curb was to be placed. The hot-mix was delivered to the job in an insulated truck covered with heavy tarpaulin. A small amount of the mix was dumped from time to time on a platform dragged behind the truck from which the mix was shoveled to its position and trued up by a raker. The mix was then compacted with a steel tamping plate ½″ thick by 9¼″ wide by 10″ long welded to the shank of a paving breaker tool. To this plate was welded a ¼″ plate 2″ wide at an angle of about 30° to the horizontal. This plate was dragged over the newly laid hot-mix by one laborer as another held the paving breaker upright which vibrates the plate that compacts the mix to the desired density.

For such work the only special equipment required is the tamping plate and its cost is minor. While in this particular project the surface of the curb was a plane, it could be made to any other cross-section by the use of a tamping plate conforming thereto. The 4″ outer curb allows for 1″ compaction. The whole operation is very simple and the work progresses rapidly. A small crew constructed 2,500 lineal feet in nine hours. The superintendent on the project states that the actual field labor cost itself was no more than 3¢ per lineal foot.

USE OF SLIP-FORM PAVER

to Construct Highway Ditches, Curbs and Sidewalks

Slip-form paver operation. *See description below.*

The principle of laying and compacting hot-mix asphalt mixtures *in one operation* on intricate cross-sections has been under consideration for some years. Considerable progress has been made since the war in these studies and the development of the slip-form paver appears to be the answer in most cases for the laying and the satisfactory compaction of special sections by machine methods.

A slip-form paver would consist essentially of a hopper for the hot-mix, mounted on a frame, which would carry a spreading template and an ironing template. The ironing template, heavily weighted by the machine itself, should strike the mix at such an angle after the spreading that densities of from 92% to 95% of laboratory compaction could be obtained readily in one pass of the machine.

Such a method of laying hot-mix asphalt has been successfully used in linings for canals and reservoirs, where a high degree of density is required. A rich mix, with a dense graded aggregate and a 50-60 penetration asphalt, is normally specified for this type of construction.

The above picture shows the operation of a slip-form paver on the slopes of the Baldwin Hills Reservoir in Los Angeles, California. This type of machine could be adapted, *by changing the shape of the templates shown in the rear of the machine, to the "one operation" cross-section required for the highway ditch or gutter, curb, and sidewalk to be constructed.*

LONGITUDINAL CROSS-SECTION OF ASPHALT CUTOFF WALL

ASPHALT CUTOFF WALL AT CLAYTOR DAM

Looking across Claytor Dam to north bank of New River. Showing, at upper right, ridge leading from dam abutment to rock structure under asphalt plant.

In 1938, what was then termed "a unique bit of dentistry" was practiced on Mother Earth by engineers of the Appalachian Power Company, with technologists of the Asphalt Institute co-operating. Into the cavities, beneath the stone bluff of the northern abutment of Claytor Dam, in a tremendous filling, they poured 4,470 tons of hot asphalt mix. By this operation, they completed an impervious cutoff wall, successful then and *still successful now in 1951* in providing a perfect seal against seepage. Asphalt has been stopping leaks for thousands of years but, as this instance involved some pioneering engineering practices, its effective use as herewith described constitutes an important development in present-day dam construction.

In the Blue Ridge section of Virginia, on New River, between Radford and Dublin, the Appalachian Power Company, in completing its Claytor hydroelectric project, found it necessary to stop underflow through the north abutment of the dam. The rock cliff at this "key" point disappeared underground a short distance beyond the crest of the slope and the overburden was found to be residual clay containing some beds of water-borne gravel and a few boulders. Below the clay the rock was a yellowish gray dolomite stratified with shale containing bedded chert.

The rock was then uncovered and intensively explored. Due to solution, the elevation of the rock surface was extremely variable and the formation contained many water passages and deep pockets filled with clay. These were excavated and, to give form to the cavities, a sheeted trench was constructed 340 feet long, averaging less than 4 feet wide and ranging from a few feet to 150 feet in depth.

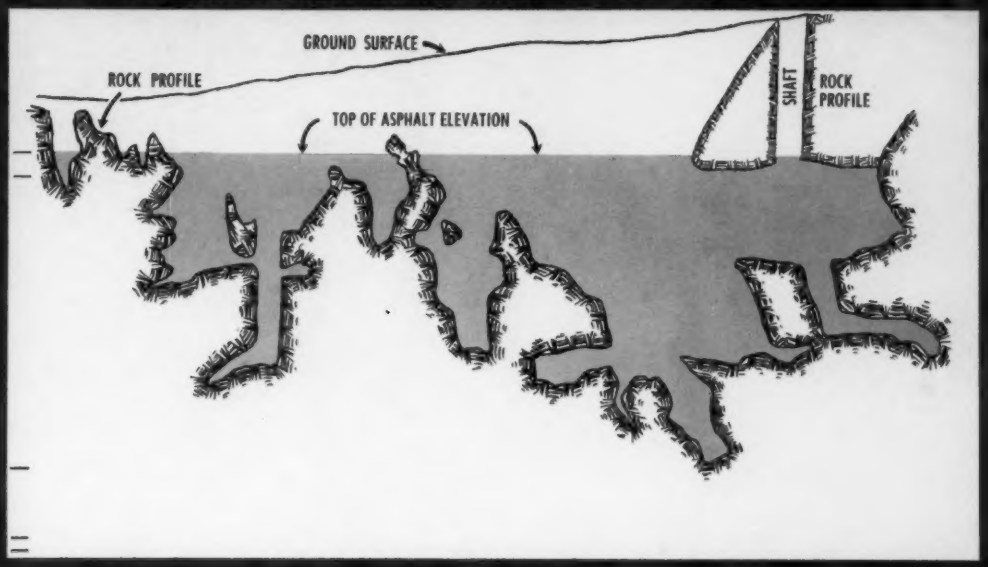
The surface of the rock was below Elevation 1,850 (4 feet above high water level) for a distance of about 255 feet and, as there was some doubt as to the ability of the overburden to resist excessive seepage, it was decided to backfill the trench below this elevation with some impervious material.

CHOICE OF SEALING MATERIAL

For this purpose, consideration was given to the use of reinforced portland cement concrete, to puddled clay, and to asphalt. Reinforced concrete was rejected because it lacks flexibility and would have been expensive and difficult to place because of the narrow width and great depth of the trench. The use of reinforced concrete would have required the removal of the trench timbering, which had been in place for many months. Although the timbering was strongly braced, there was sufficient "working" of the members to indicate that it was sustaining heavy pressures, hence its removal would have been an extremely hazardous undertaking. Puddled clay was considered to have some of the objectionable features of reinforced concrete, particularly as it too would require the removal of the timbering.

Flexible, impervious asphalt became the most obvious choice to solve the problem

LONGITUDINAL CROSS-SECTION OF ASPHALT CUTOFF WALL



but, as there was no record of its use as a core-wall material in a dam previous to this time, the Asphalt Institute was consulted and asked to design a mixture of asphalt and aggregate which would remain permanently "rubbery" and flexible at 56 degrees F., the approximate constant temperature of the earth at the depth to which the diaphragm-wall would be buried. Such a flexible diaphragm would adjust itself to any of the forces caused by settlement and movement of the ground to which it might be subjected without cracking and seal any leaks which might occur in the future due to solution of the rock surface upon which it rested.

ASPHALT AND AGGREGATE SPECIFICATIONS

After tests with various sizes and gradings of aggregate, the Institute recommended the following specifications for asphalt and aggregate in the proportion of 11½ percent to 88½ percent. (Dolomite sand was specified as it was manufactured on the job.)

ASPHALT

Specific gravity	1.015
Softening point	105 deg. F.
Penetration (77 deg. F.)	190
Furol viscosity (210 deg. F.)	916 sec
Flash test	620 deg. F.

DOLOMITE SAND

	Percent by weight
Passing ¼ in. retained on No. 10 sieve	19.5
Passing No. 10 sieve retained on No. 40 sieve	39.5
Passing No. 40 sieve retained on No. 100 sieve	16.5
Passing No. 100 sieve	24.5
	100.0

CONSTRUCTION PROCEDURE

The placing of the mixture was very simple after the following preliminary work had been performed. A standard premix plant, such as is used for highway work, with asphalt heater, aggregate drier, batch weigher, mixer and tanks, was set up at the site. The old wooden trench braces were removed without disturbing the sheeting and replaced with steel pipe jacks which were made in various lengths on the job. (The jacks, which were filled with cement grout to prevent the passage of water through them, were to be left in place.) The surfaces of the rock were wire brushed and primed after the trench had been thoroughly cleaned of all foreign matter.

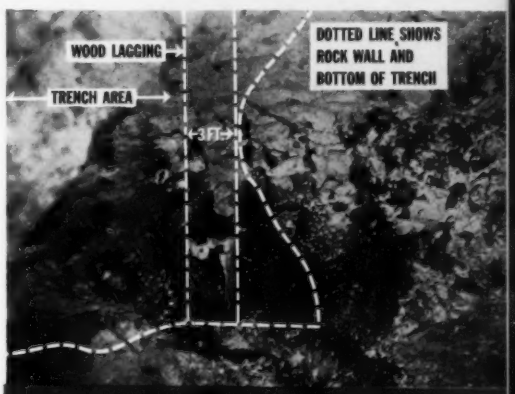
Weighed batches of dried sand and heated asphalt were mixed for three or more minutes at an average temperature of 335 degrees F. and the mixture was taken in tight-bodied trucks to the trench and dumped in suitably placed hoppers which discharged vertically.

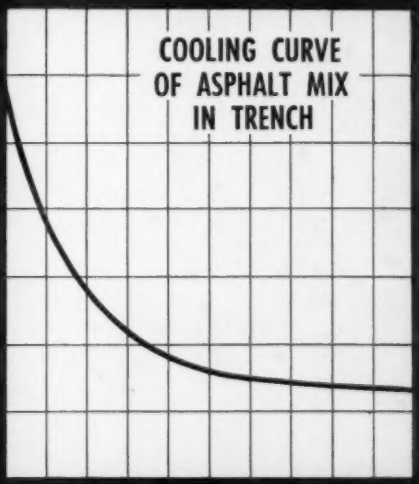
Inasmuch as the asphalt mixture stayed in a liquid or semi-liquid state for some days, it was possible to pour at a rate governed only by the physical demands of the work. The pressure caused by the weight of the high lifts, as well as the weight of succeeding pours on the fluid mass, not only compacted the mixture in the trench but forced it into all of the surrounding spaces to the point of completely embedding the sheeting.

The solution passages were so tightly packed with the asphalt that no air pockets remained and even the small cracks in the rock were filled for some distance from the trench. This was demonstrated by a small inspection drill which was driven a short distance through the rock to a section of the completed diaphragm and also by diamond drills which later encountered stringers of the asphalt several feet from the trench.

Resistance thermometers were placed in the asphalt and a record was kept of the daily readings until the wires were lost. As the temperatures had closely approached normal by that time, no effort was made to continue the readings and the trench was backfilled with clay from the top of the asphalt to the ground surface.

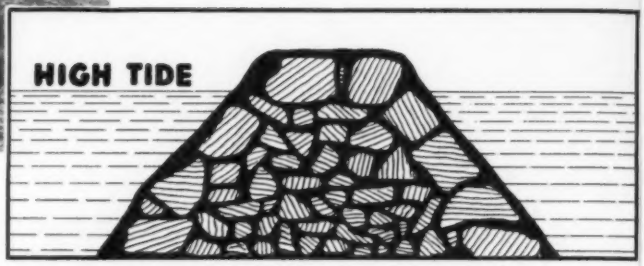
Photos by Frederick C. Field, Chemist, The Asphalt Institute, with Adaptations of his cross-section and chart.





DEVELOPING ASPHALT'S WIDE RANGE

The Galveston Jetty, as made solid with asphaltic concrete in 1935, still effectively protects the harbor today.



Typical End-Section of Asphalt Jetty.

GALVESTON JETTY

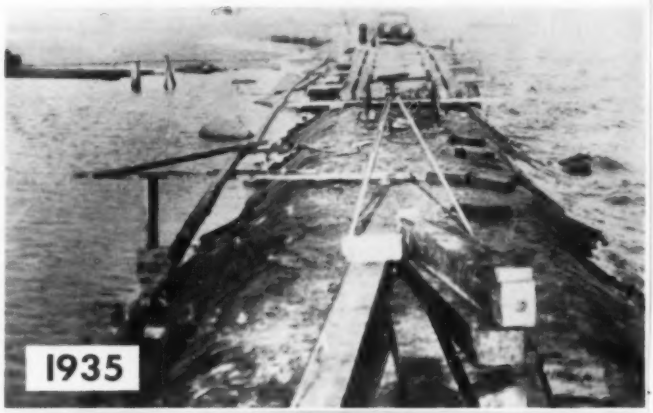
In August 1935, the U. S. Engineer Office at Galveston, Texas, was authorized to repair the rubble jetty at the entrance to the Galveston Channel, with asphaltic concrete. Following tests and extensive research, and with the Asphalt Institute cooperating in developing the methods and materials to be employed, actual placement of the asphalt-mix was undertaken.

CONSTRUCTION PROCEDURE

Various asphaltic mixes were used, one of the most successful consisting of 18 percent 30-40 penetration asphalt, 12 percent loess and 70 percent Galveston beach sand. The material was placed at 400° F. and care was taken that mass dumps into the rock rip-rap were made in order that the material would retain its heat, and the maximum flow could be obtained throughout the voids in the rip-rap, both under and above the sea water. Vibrators were also used to facilitate this action.

The sealing and stabilizing of the Galveston Jetty with asphalt was the largest repair installation of its kind ever undertaken. It has proved very successful and, in spite of the terrific pounding it has taken from the Gulf storms, only a few minor failures have been noted in the past fifteen years. This same performance history has been repeated in this type of installation throughout the world.

The foregoing procedure involved the *pioneering step* of depositing the hot material under water in bulk to settle, take form, and bond up under its own weight, aided by vibration. Thus the mixture used, as recommended by the Institute, was completely successful, thereby adding a new construction method to those available for underwater work.



Above: Construction Picture of Asphalt Jetty. Finished asphalt cap in foreground.

Below: Protecting Galveston Harbor successfully from Gulf of Mexico storms.

E OF USES

Asphalt Roller Skating Rink, with Plastic Finish, at Costa Mesa, California. Constructed as an open-air rink in 1947; building completed in 1950.

SKATING RINK

A large amount of asphalt roller skating rink construction has been completed in Southern California. For this work, local specifications and standards have been devised which are briefly outlined here to show the general scope of such projects.

Important considerations relating to the work to be done following a study of local conditions, selection of subbase and asphalt design formula, are included under these headings: Compaction, Aggregates, Percentage of Asphalt, Floor Grades, Surface Dressing and Plastic Finish.

PLASTIC FINISH

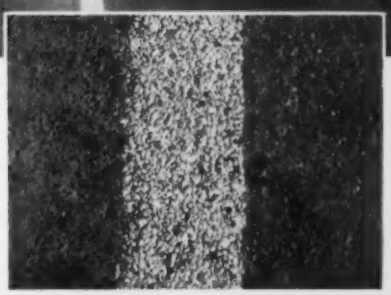
Under the last-named heading the plastic finish recommendation for roller skating rinks is as follows:

The asphalt floor should be allowed to stand at least one week before applying the surface dressing and at least two days longer before applying the plastic. The plastic should be applied in at least five coats. The first two coats should be applied by a spray at the rate of approximately 1,500 square feet per gallon for each coat. Following this, two color coats may be applied by squeegee. This should be done under the supervision of an experienced applicator. Spreading should be done at the rate of approximately 500 square feet per gallon for each color coat. An additional coat of clear plastite applied at the rate of 1,000 square feet per gallon may be necessary for suitable surface texture.

ASPHALT CENTER STRIPE

Every State Highway Department is looking for new ways of reducing maintenance costs. Some are making very satisfactory savings on the one item of traffic stripe, by using the raised asphalt and stone construction in place of the usual painting. Normally painting must be renewed twice each year but the asphalt and stone stripe has an effective life ranging from five to ten years. In fact some have been in use since 1939 and are still in good condition.

Today there are thousands of miles of these long-lasting asphalt traffic stripes in Texas and Oklahoma. Material requirements include approximately 65 gallons of asphaltic material and $2\frac{1}{4}$ cubic yards of $\frac{3}{8}$" maximum size aggregate for one mile of 6" width stripe. Actually $1\frac{1}{2}$ cubic yards of aggregate per mile would be sufficient to cover a 6" stripe if there were no waste, but as a 9" width aggregate spreader is used for this work, a slight allowance for waste must be made.



Well-marked asphaltic concrete surface on U. S. 290, near Houston, Texas.

Closeup of the 6" width asphalt and white limestone center stripe.

Photos by Wallace

ASPHALT INSTITUTE ENGINEERS

JAMES M. LACKEY

HERMAN C. HELMLE

James M. Lackey, from his headquarters at 523 West Sixth Street in Los Angeles, directs the local engineering activities of The Asphalt Institute throughout Southern California and Arizona.

Now seventh in years of service on the Institute's district engineering staff, Mr. Lackey has also a background of over twenty-two years of service in the California Division of Highways. There he supervised asphalt paving in District VII, centered in Los Angeles, as Senior Highway Engineer.

From his headquarters at 520 South Sixth Street in Springfield, Illinois, Herman C. Helmle extends the Institute's local engineering facilities throughout the states of Arkansas, Illinois, Iowa, Minnesota, Missouri and Wisconsin.

Mr. Helmle, eighth in years of service on the district engineering staff, was affiliated with the Illinois Division Highways for thirty years, for the latter twenty years of this time supervising the inspection of the state's bituminous road construction.

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